Search for large extra dimensions in CDF

SUSY06

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Pierre-Hugues Beauchemin
University of Toronto

On behalf of CDF Collaboration

Strategy of the measurements

- The new physics searches of interest here are based on three different signatures:
  - 1-jet + MET signals (unbalanced energy in detector)
  - High mass resonance decaying to lepton pairs
  - High mass resonance decaying to photon pairs
- Idea: direct comparison of each signal to their estimated SM background.

These searches are not based on any new physics assumptions and the results are therefore applicable to any model which predicts such signatures.

- We will interpret the results in terms of extra dimensions (limit on extra D.) at the end.

Monojet + MET search

Data sample

- **Using ~1.1fb^{-1} of data, we have enough statistics to be able to make data-driven estimates of the major backgrounds.**
- **The data sample comes from a trigger on events with a 100 GeV jet (fully efficient for jets with E_T(corr) > 150 GeV).**
- **The most important backgrounds are:**
  - **Electroweak (1-jet + $Z \to \nu\nu$ and $W \to \ell\nu$: ℓ is lost)**
  - **QCD (jets mismeasured) $\to$ small (~6% of total bkg)**

Monojet events selections

- To select our signal event candidates:
  - The leading jet must have E_T(corr) > 150 GeV to ensure that the trigger is fully efficient;
  - Large missing energy is expected from the escaping particle (MET > 120 GeV);
  - The leading jet must point to a well instrumented calorimeter region ($|\eta_{det}| < 1.0$);

Monojet events selections (continue)

- A 2nd jet of lower energy ($E_T(2) < 60$ GeV) is tolerated to increase the acceptance (ISR/FSR)

- To remove the charged lepton of W + jets events, we require no isolated tracks with $P_T > 10$ GeV/c and an Em fraction < 0.9

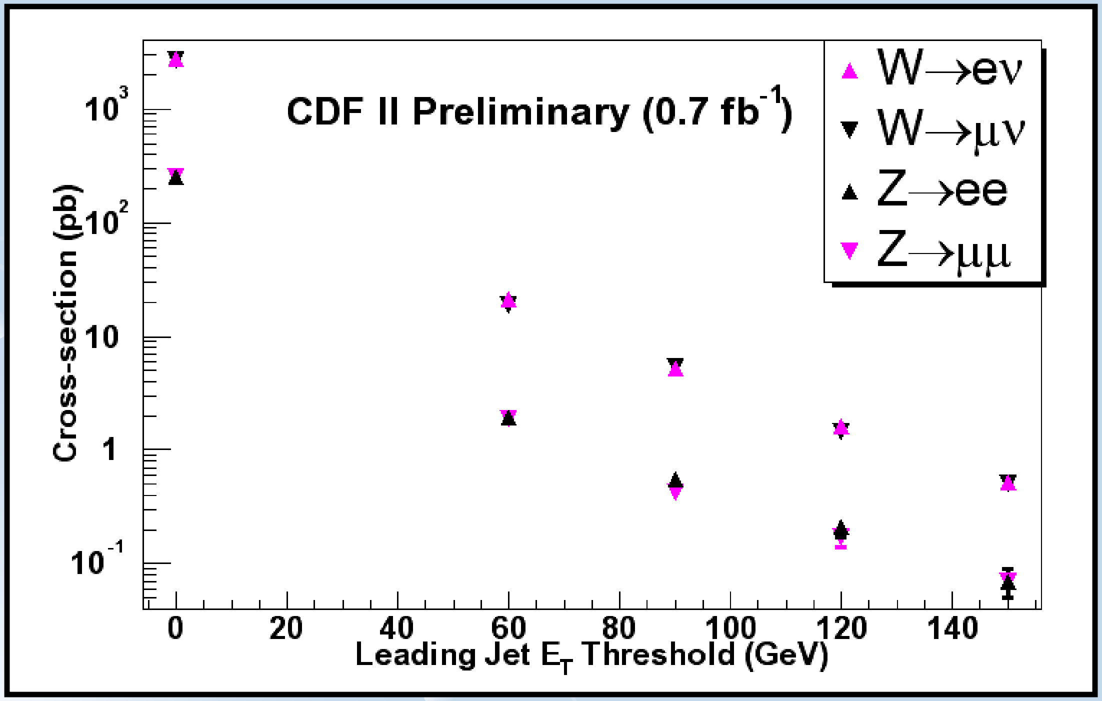
- To reduce QCD bkg, the MET must not be in the same azimuthal direction (ϕ) as any jets.

Electroweak backgrounds

- **To make a data-driven estimate of Z $\rightarrow \nu\nu$:**
  - **1-jet+W/Z (Z$\rightarrow\ell\ell$, W$\rightarrow\ell\nu$, ℓ = e, μ) cross sections are measured on a high P_T lepton data sample ;**
    $\Rightarrow$ Four statistically independent measurements
  - **W cross sections are normalized to Z ones using the R factor (theoretical ratio between W$\rightarrow\ell$v and Z$\rightarrow\ell\ell$ cross sections). NLO calculations were performed with MCFM;**
    $\Rightarrow$ Uncertainties much smaller on R (ratio) than on individual cross sections
  - **Multiply all the four cross sections by ~6 (Z$\rightarrow\nu\nu$ has different branching ratio and couplings than Z$\rightarrow\ell\ell$) and combine them.**

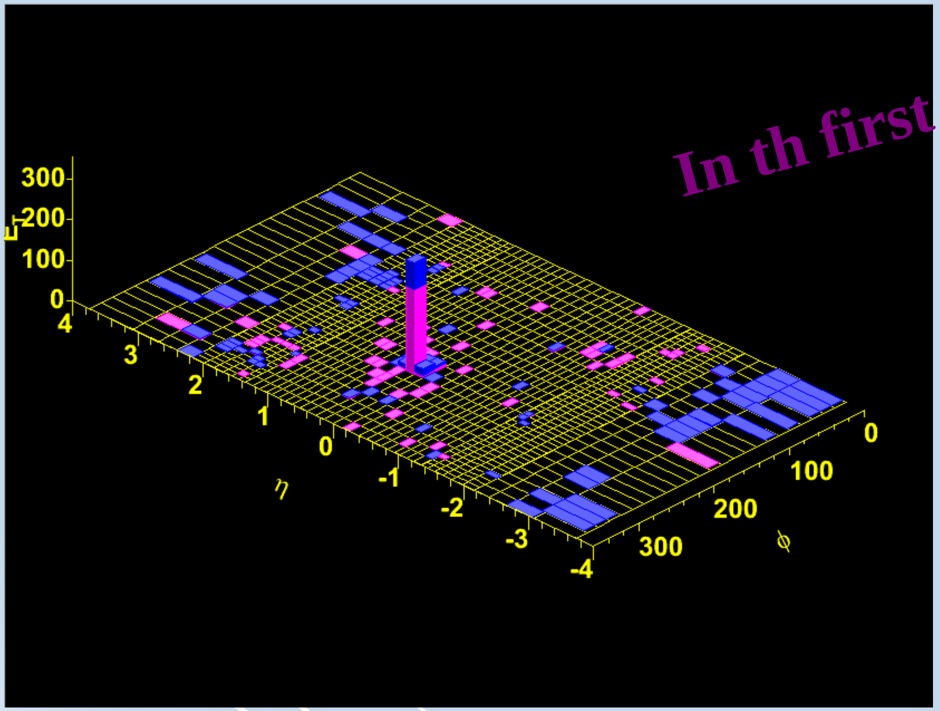
- **To estimate the W→ℓν background, the acceptances on the selection criteria presented above are computed on W→ℓν (ℓ = e, μ, τ) Monte Carlo.**

  The number of event bkg is then normalized to the measured cross sections for W's

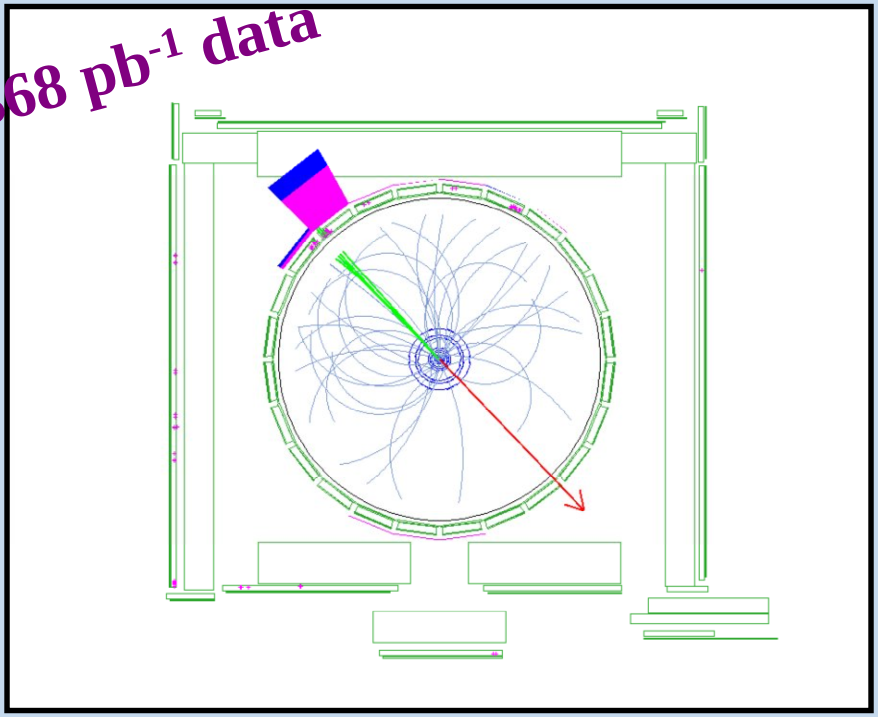


Electroweak background well understood!

Most Energetic Event display

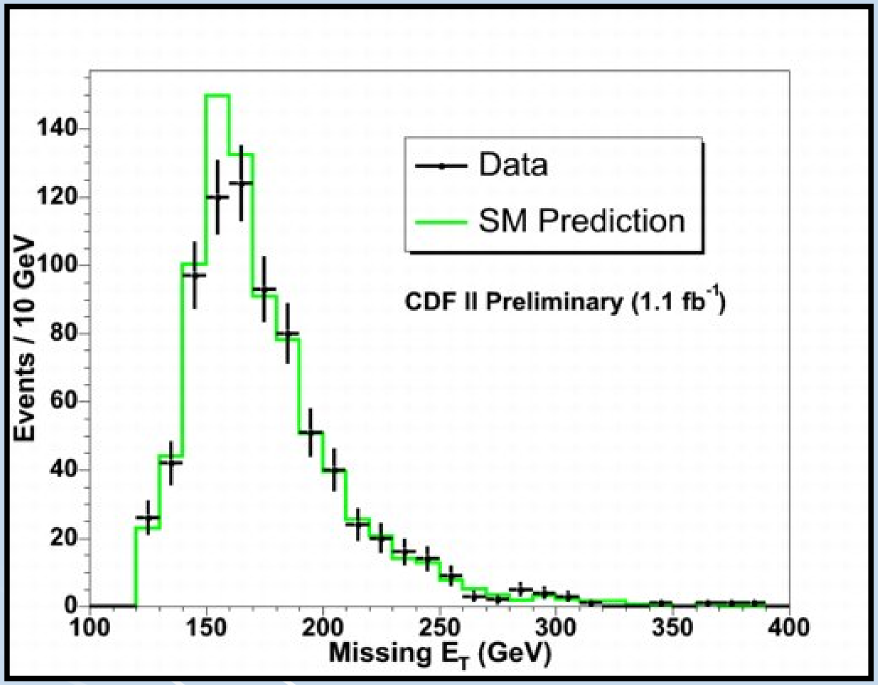


In th first 368 pb^{-1} data



Jet E_T = 384 GeV, Missing E_T = 390 GeV

Results



Background	Events
$Z \to \nu\nu$	394 ± 29 events
$W \to \tau\nu$	189 ± 19 events
$W \to \mu\nu$	118 ± 11 events
$W \to e\nu$	57 ± 6 events
$Z \to ll$	8 ± 1 events
QCD multi-jet	39 ± 14 events
Non-Collision	6 ± 6 events
Total expected	811 ± 68 events
Data Observed	779 events

There is no evidence for any new physics!

High mass resonance search

Dileptons

- **Measurement strategy:**
  Compare the observed dileptons invariant mass distribution above 150 GeV/c^2 to the one expected from the sum of all SM backgrounds.

- **Data are collected in two different samples:**
  - **High P_T electron triggers (E_T >18 GeV)**
  - **High P_T muon triggers (P_T > 18 GeV/c)**

- **Electrons and muons are analyzed separately:**
  - **Dielectron candidates (E_T>25 GeV) are selected in the central ($|\eta|$<1.1) and plug (1.2<$|\eta|$<3.0) regions of shower Max detectors.**
  - **One muon is selected in the central region covered by the muon trigger ($|\eta|$<1.0) while the other must at least be an isolated track up to $|\eta|$<1.5. Both must have P_T>20 GeV/c**

- **Backgrounds to dilepton signal come from:**
  - **SM Drell-Yan ($Z^0/\gamma^* \rightarrow e^+e^-$, $\mu^+\mu^-$)**
  - **QCD and W+jets**
  - **Higher order Electroweak processes (tt, $\tau\tau$, WW, WZ)**
  - **W+γ and $\gamma\gamma$ (for dielectron channel)**
  - **Cosmic rays (for dimuon channel)**

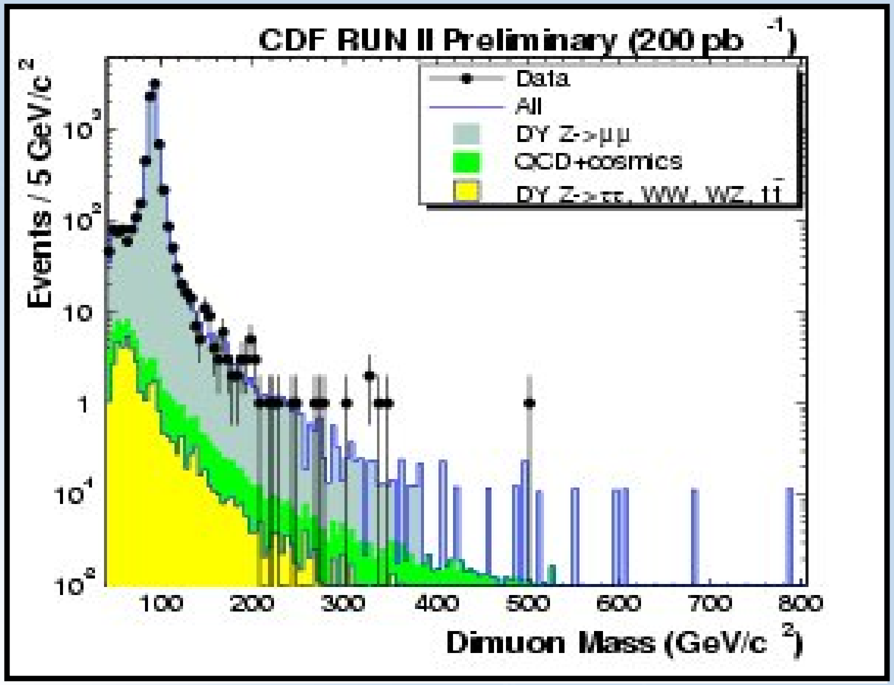
- **Drell-Yan invariant mass distributions are provided by MC normalized to data in the Z^0 mass window.**

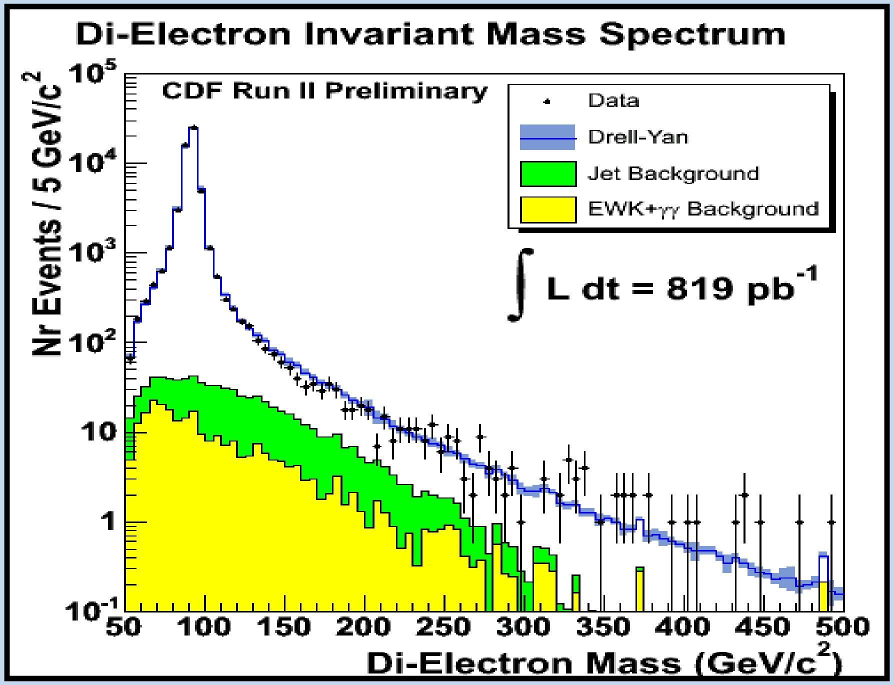
- **The non-dielectron backgrounds are estimated from the sideband regions of the two isolation vs isolation distributions, extrapolated to the signal region.**

- **Cosmic rays contribution is estimated from a sample of cosmic rays which pass the signal selection cuts.**

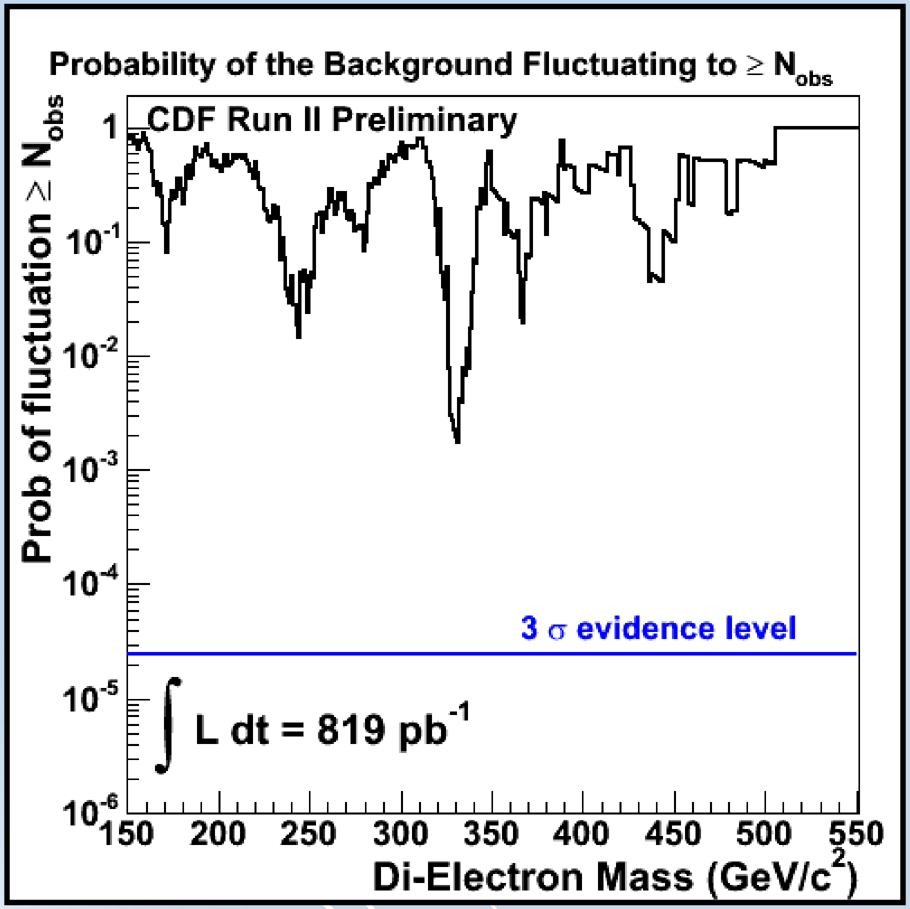
Results: invariant mass distributions

- **Dimuons**
  - **L=200 pb^{-1}**
- **Dielectron: an update**
  - **L=819 pb^{-1}**





Probability of bkg fluctuation



- **Using the most recent dielectron mass distribution (most stat.), the probability for the bkg to fluctuate to the level of data or higher is calculated, using Poisson statistics.**

There is no evidence for any new physics anywhere in the mass spectrum!

Di-photons

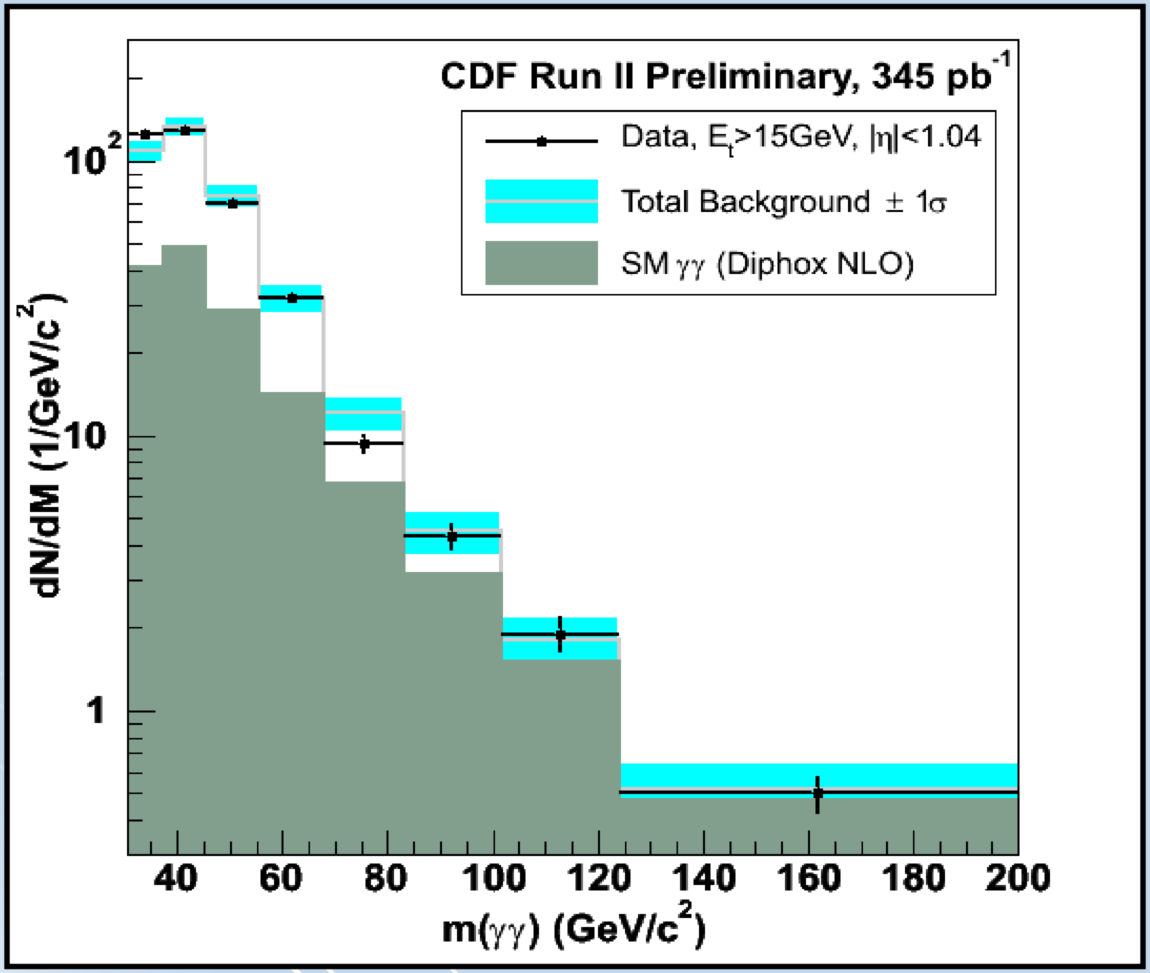
- The measurement strategy is similar to the one of the dilepton channels
- The sample corresponding to 345 pb^{-1} of data is collected from 4 different triggers.
- Photons are selected with tighter criteria:
  - E_T>15 GeV in the central region (app. $|\eta| < 1.04$)
  - Sum P_T of all tracks which point the to photon cluster is less than 2 GeV/c
  - Isolated
  - Invariant mass between two γ greater than 30 GeV/c^2

- There are two significant backgrounds:
  - SM diphoton production
  - single photon + jet faking a photon (leading π^0)

- The invariant mass distribution for the SM diphoton bkg is estimated with NLO MC (diphox).

- Efficiency corrections based on Pythia+GEANT are applied.

Results



Update expected this summer

The observed invariant diphoton mass spectrum is consistent with the expected background

Interpretation of the results

- No new physics has been found in the three channels presented above.

- The results will be interpreted in terms of limits on the parameters of extra dimensions models.

Why look for extra dimensions?

- Extra compactified dimensions are an essential ingredient to many of the best attempts in solving fundamental problems of high energy physics like the cosmological constant problem.

- It is a well motivated concept because string theory predicts them (as motivated as SUSY).

- They can be big enough to be manifest at the energy frontier (Tevatron)

$\Rightarrow$ They <u>can</u> be observed experimentally, so we <u>must</u> look for them

Large Extra Dimension scenario (ADD)

- **Gravity couple strongly in 4+n dimensions**
  ⇒ D-dim. Planck scale as big as weak scale
- **Gravitons escape in the large bulk of extra dim.**
  ⇒ continuous KK spectrum

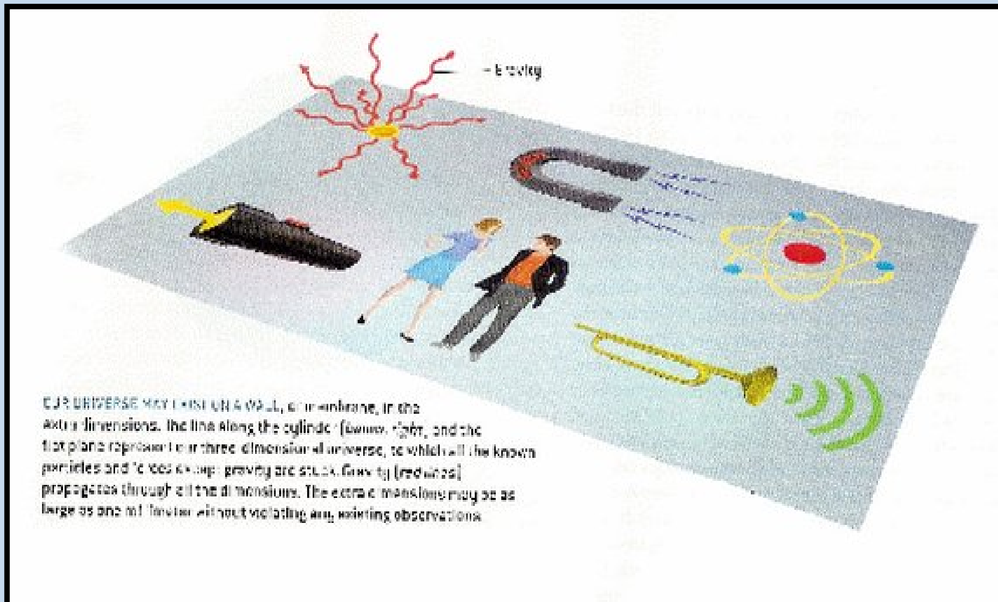
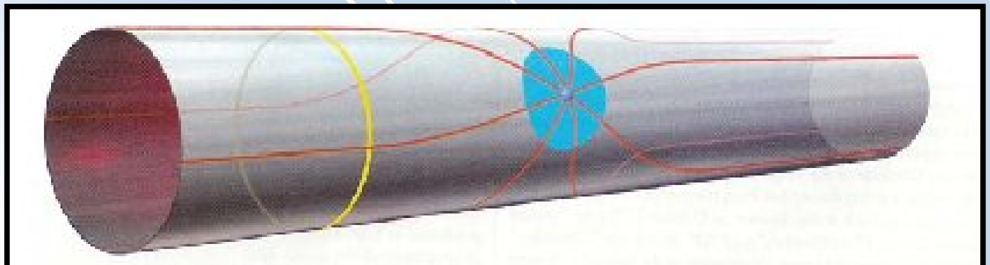


image de Sc. Am. 12/2 (2002)

$$\mathbf{M_{Pl}^{2} \approx R^{n} M_{D}^{n+2}}$$

$$R \approx 10\mu m \rightarrow R^{-1} \approx 1 meV \rightarrow M_D \approx TeV$$

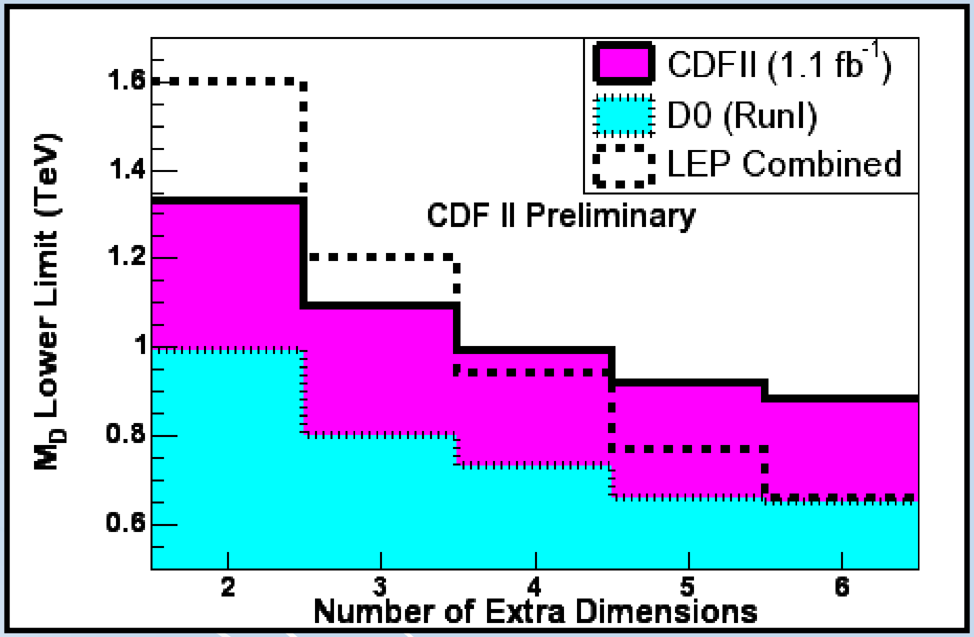


Parton level processes:

qq→gG, qg→qG and gg→gG

⇒ Jet + EtMiss

Limit from monojet search on Large Extra Dimension (ADD)

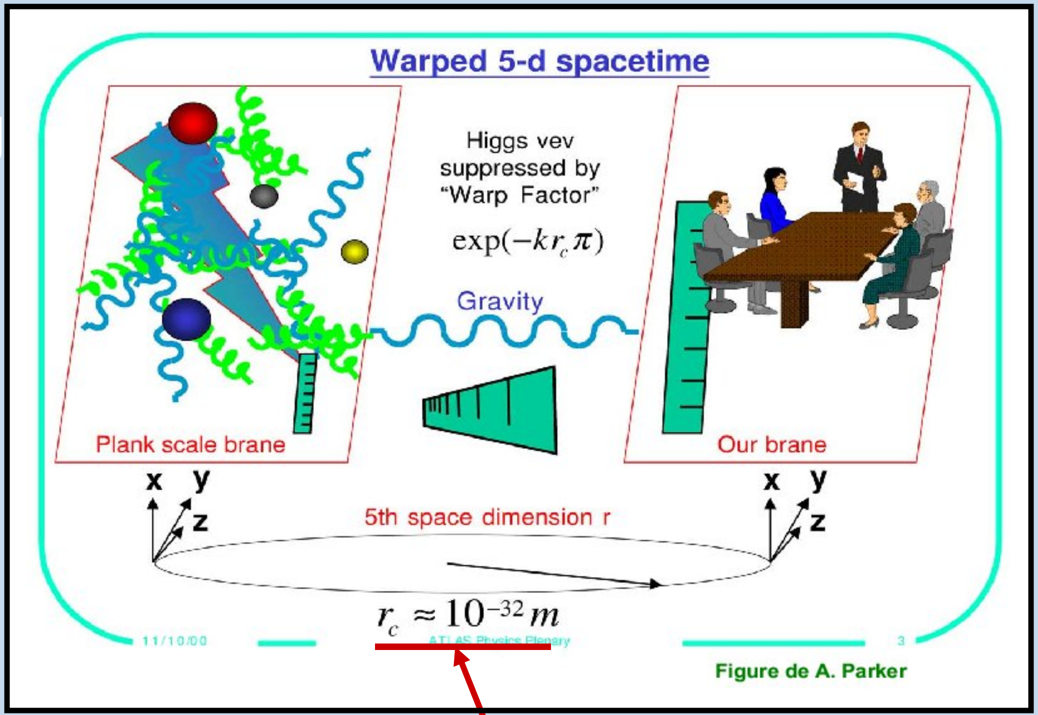


n	M_D (TeV/c^2) (K=1.3)	R(mm)
2	> 1.33	< 0.27
3	> 1.09	< 3.1 x 10^{-6}
4	> 0.99	< 9.9 x 10^{-9}
5	> 0.92	< 3.2 x 10^{-10}
6	> 0.88	< 3.1 x 10^{-11}

Eöt-Wash limit: $R < 1.3 \times 10^{-1}$ mm (n=2)

Warped Extra Dimension (RS)

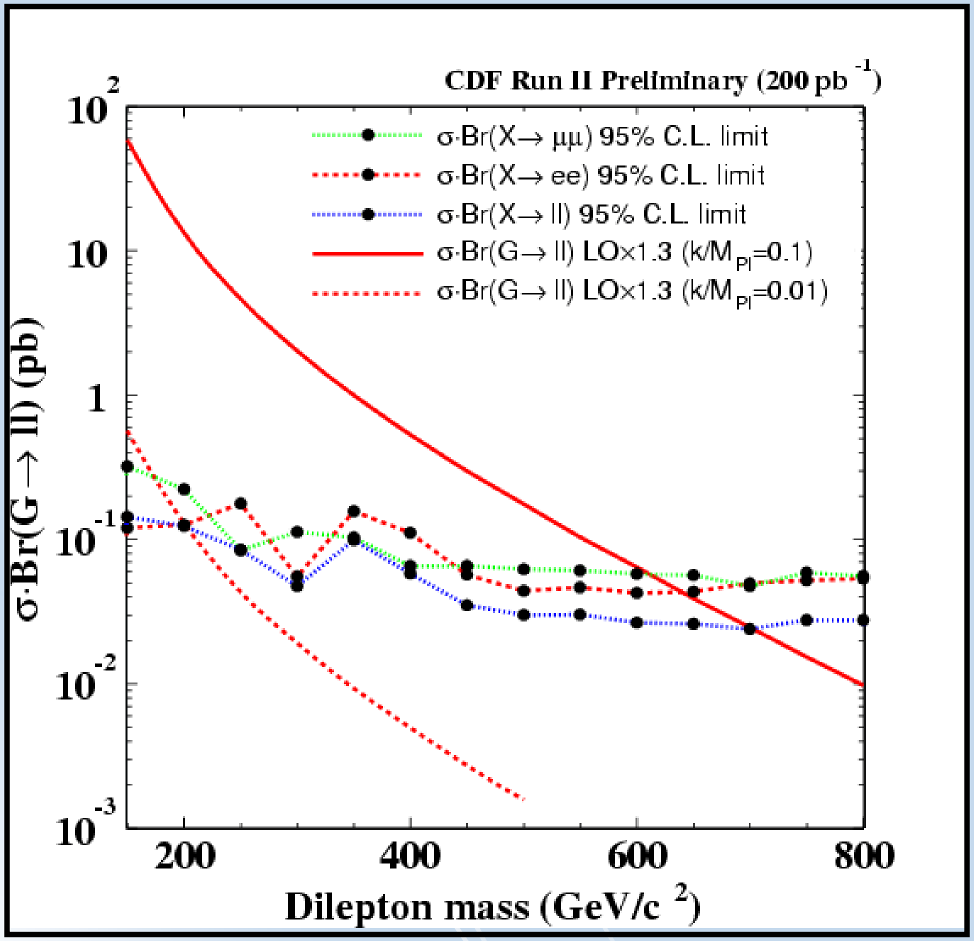
- **Non-factorizable metric**
  ⇒ warp factor
- **Fund. Graviton coupling**
  $\Lambda_\pi^{-1} = M_{pl}^{-1} e^{kr\pi}$
- **KK spacing on our brane:**
  $m_n = k\pi\Lambda_\pi / M_{pl}$
- **constraints:**
  $0.01 < k/M_{pl} < 0.1$
- **⇒ $m_1 \sim 1$ TeV**



Small extra dim

Signature: narrow graviton resonance

Limit from dilepton searches on narrow graviton resonance (RS)

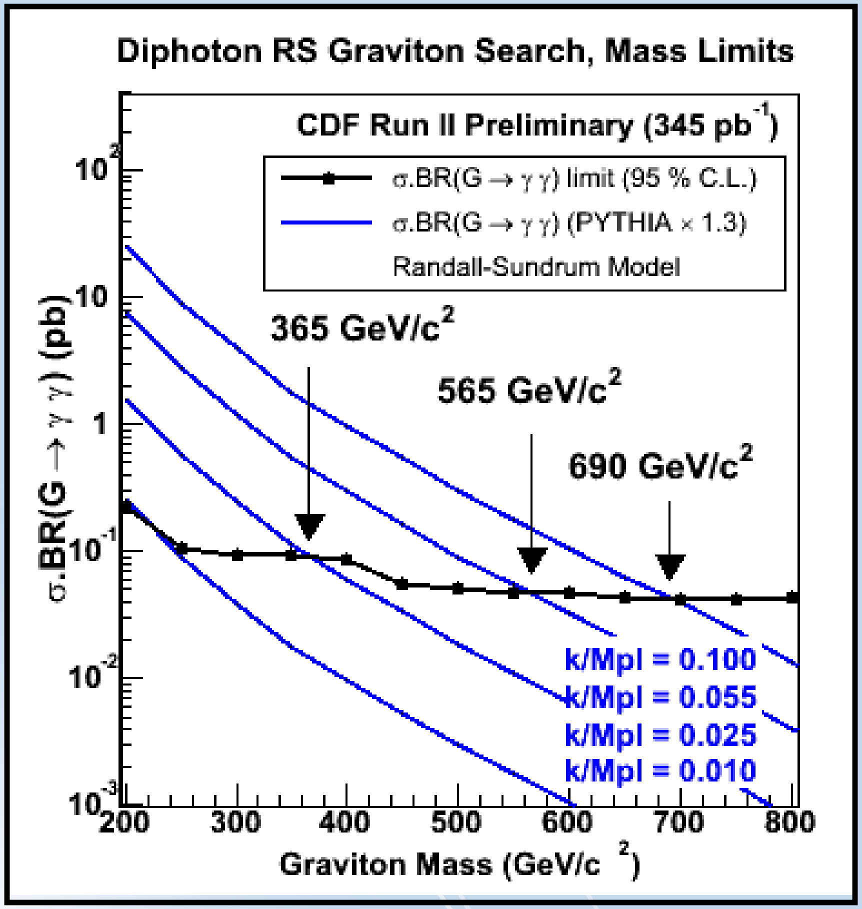


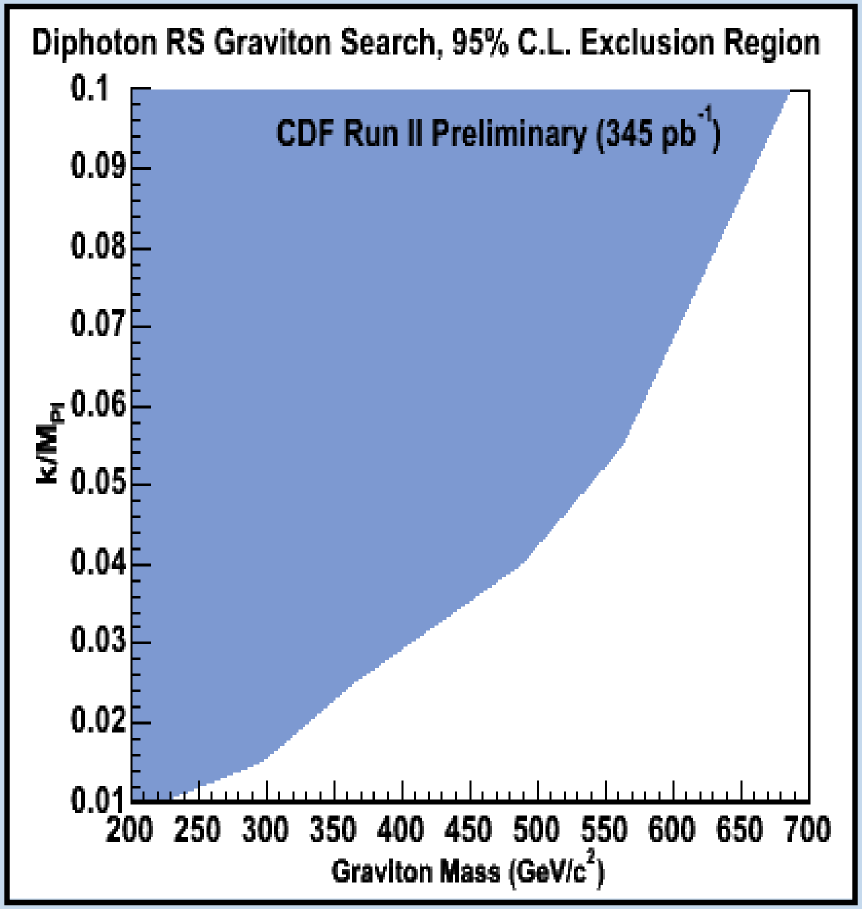
K/M_{pl}	M_{grav} limit (95% C.L.) (GeV/c^2)		
	e^+e^-	$\mu^+\mu^-$	l^+l^-
0.1	640	610	700
0.07	555	530	610
0.05	485	455	525
0.01	200	170	200

Note:

Individual channels are still very important: lepton universality

Limit from diphoton searches on narrow graviton resonance (RS)





CONCLUSION

- No new physics signal have been seen in the following signal searches:
  - Monojet + Etmiss
  - High mass resonance with dilepton sample
  - High mass resonance with diphoton sample

- Limits have been put on two extra dimensions scenario:
  - M_D>1.1 TeV in the large extra D scenario
  - M_G>700 GeV in the warped extra D scenario